ADVANTAGES OF A YEAR'S COURSE IN BIOLOGY (ZOÖLOGY, PHYSIOLOGY, BOTANY).

THIS is an age of science. The contributions of applied science to the comfort and elegance of our daily lives have been so vast as almost to defy enumeration. This is a practical age. Hence, with the great advances in the direction of applied science, there has come a demand for a fuller study of pure science, not only because scientific principles must be known in order to be applied, but also for its own sake, as an essential element in a liberal education.

This latter demand was for a long time satisfied by what was known as a "culture course," the idea being that, by a series of lectures and assigned readings, an instructor could put his eager classical students in touch with the results of scientific research. It is a cause for regret that in some quarters this kind of "culture course" has not yet become extinct.

A long step in advance was taken when these culture courses were supplemented by practical work on the part of the student himself, the purpose being not so much to store his mind with interesting facts, as to lead him, by his own direct contact with the objects themselves—which are the real facts—to an appreciation of the methods of original scientific work, and the laborious processes by which the generalizations of the science have been reached. It was right here that the supreme opportunity was given to science to demonstrate its unique value as a part of our educational system. Up to this time the average student in science gained little of real value beyond the smattering of information by which he could make small-talk in society, or illustrate his sermons. His knowledge of facts was acquired along the path of least resistance, the memory, resulting in the partial atrophy of other important mental faculties. Now, eye and hand must be trained to do the bidding of the mind. The student must learn to be accurate as an observer, discriminating

between the essential and the nonessential, the typical and the abnormal, honest in making his record of observations, candid and logical in the conclusions drawn from those observations.

Of all the sciences which have lent themselves to this method of study in the high school, none is more important than biology, since it stands in such close relation to our own personal welfare. We are the youngest of them all, and yet it is inspiring to glance back over our history, looking at it, for the present, entirely from the educational point of view. It is interesting, also, to note the closely parallel lines along which our educational ideals have passed in the two co-ordinate branches of biology—zoölogy and botany.

Glancing first at zoölogy, we see how, even within the recollection of many of us, the best schools were contented with a method of study which trained only the memory. Systematic zoölogy, or classification, lent itself readily to this style of treatment, and was almost universally taught. Then when the insufficiency of illustrative material, as viewed from the teacher's desk, began to be felt, specimens were handed out to the students, first for mere external examination, and later for internal study (dissection); and since only a limited number of forms could be studied in this way, we see morphology fairly installed as the subject-matter, and type-study as the special laboratory method. At first this was used merely as an aid to the understanding of the broad outlines of classification, but as teachers found that students were more interested in a structure when they knew what it was for, more and more attention was paid to function, or physiology. Today most of our schools are teaching this kind of zoölogy, and opinion is somewhat evenly divided as to whether the chief attention should be paid to the study of the structure of a series of types, or to the life-habits of animals. What might be called the new zoölogy—the study of the adaptations of animals to their environment, or ecology—is a natural outgrowth of the increasing attention which has been paid to the study of function.

Turning now to botany, we need not spend much time in telling how long the "classification" of plants was regarded as

the highest goal for the ambition of the investigator, as well as the proper work for the beginner, and a refined and uplifting recreation for amateurs in every walk of life. Indeed, botany remained so long the "gentle science" that even today, in some quarters, it is hardly considered a worthy occupation for men. Further, systematic botany, as taught, was confined to the study of the flowering plants, and when its immediate successor and partial contemporary, structural botany, came into prominence, that also was limited in its application. Imagine a class in zoölogy beginning its work with the comparative anatomy of vertebrates! A more rational treatment of plant anatomy soon brought it into proper relations to classification and development, and we reached, at last, a true morphology. Greater attention was now paid to the flowerless plants. The "dirty scums" of the pools were found to consist of objects full of beauty and interest. The bark of the trees, the dirt in our flower-pots and greenhouses, the dripping rocks in our glens, all had their part to contribute to the new old subject. Then the inevitable happened in botany, just as it had in zoölogy. No teacher can arouse much interest in mere structure, if its function, the reason for its existence, is not understood. It was a professor of Latin in one of our largest universities who, hardly five years ago, asked a botanist what possible connection there could be between physiology and botany! There *is* a very real connection between them, and our Latin professor might do well to glance over the rapidly increasing number of excellent textbooks and laboratory guides in plant physiology.

Thus far, if the truth be told, botany was merely following in the footsteps of zoölogy. But we can now show where botany has at last taken the lead. Kerner's *Natural History of Plants* is an old book, but it is read more and more every year. The work of Haberlandt on the *Physiological Anatomy of Plants*, and later that of Warming on *Ecological Plant Geography*, have brought into prominence a phase of botany so natural that we seem almost to have known it always, so interesting that we might well be asked why we neglected it so long. The teaching of zoölogy had long been established on the basis of morphology and physi-

ology, when the work of the botanists stimulated their brethren to an increased attention to the questions of animal ecology. Thus, in the "Twentieth Century Series," Jordan's *Animal Life* follows Coulter's *Plant Relations*. Note also the increasing interest in the study of the habits of birds and insects.

In physiology, also, there has been an advance, especially when, as will be shown later, it has followed a course in zoölogy. In former times far too much time must needs be spent in the study of the anatomy of the body, and the writer can remember distinctly the hard work he had to make a poor memory keep such things as the bones of the body and the cranial nerves in proper order. Today, while we are still obliged to study the anatomy of the body, we are paying more attention to the functions of the various organs. This gives us a much better foundation for a rational instruction in hygiene—a condition which we all welcome, even though we may think that the alcoholic appendix is abnormally large!

Then many of us are finding an increasing satisfaction in teaching what is known as *cell*-physiology. Without going at all into details, this is a universal, a general physiology, its data being derived from the study of plant cells as well as those of animals, its conclusions being applicable alike to both. Treated thus, human physiology is but a special phase of a much more general subject. It may be said with safety that this is the highest form of physiology, since it makes it a part of the general science of biology, co-ordinate with general morphology.

In this hasty sketch no attempt has been made to point out the specific influences of one science upon the other, except in the most casual way. We may now consider some of the influences which each of them has exerted, or may exert, upon the others.

The study of zoölogy has, as we have seen, passed from systematic zoölogy to morphology and physiology. How does this affect human physiology? First of all, the study of a series of graded types gives the student a knowledge of comparative anatomy, so that when he comes to the physiology he need not spend so much time on the anatomy of the body, but

can pay more attention to physiology proper—a practical gain of very great importance. Then, too, it gives a chance, by the study of the lower, simpler forms, to see what are the fundamental physiological functions. Nutrition, respiration, irritability, all are seen in the protozoa, reduced to their lowest terms, separated from all complicated anatomical machinery. Nutrition is the nutrition of the cell; respiration is the respiration of the cell. In the higher animals there is simply a division of labor between different kinds of cells. Ask a class in physiology the fundamental purpose of respiration, and how often the answer will be, "to purify the blood." But if that class had been studying the respiration of a graded series of types from amœba up, it would see that what the physiologies call the "internal respiration" is the real respiration, the respiration of the cells, and that the question as to whether the gas exchange (external respiration) shall be effected through a moist skin (as in the earthworm), or gills (crayfish), or lungs (man), is simply one of adaptation to a particular environment, the blood being in all cases simply a medium of exchange between the outer world and cells which are in the interior of the body. This is but a single illustration of the importance of a comparative study of the physiology of the types used in zoölogy.

That zoölogy has by a good example in times past helped to bring about much-needed reforms in the teaching of botany cannot for a moment be doubted. We have already shown how much earlier zoölogists adopted methods of teaching which are of standard value today. Botanists have done well to follow their lead. It stands to reason, too, that a well-trained zoölogist, carrying over to his botany class the results of the careful methods of work used in zoölogy, will produce equally good results in botany. But it should be emphasized right here how much botany has suffered at the hands of those self-styled "biologists," who are in training and sympathies merely *zoölogists*, and whose only knowledge of botany comes from a day or two spent on protococcus and spirogyra, and a long-forgotten course in Gray's *Lessons*. We botanists ask for no better training in botany than in zoölogy, but we do want it to be equally as good.

In speaking of the influence of physiology upon zoölogy and botany, it is admitted by every live teacher that physiology is to a good course in either zoölogy or botany very much what the juice is to an orange. With it, there is plenty of life and interest. The trouble with our old-style botany courses was that, in our administration of the legacy handed down to us by Professor Gray, we made the mistake of leaving the physiology out. The result was that dried plants were considered nearly as valuable as living ones, and often even more valuable, and we became mere dealers in baled hay!

Then, too, the higher physiology, the physiology of the cell, will act as a valuable check on the teacher, who must be careful to employ terms in describing the physiology of the plant in the same sense in which they were employed with animals. For example, if he has taught the proper meaning of digestion and assimilation in zoölogy, he will be obliged to stick to his definitions when he comes to botany. After a good course in animal morphology and physiology, a teacher (or a text-book) ought to expect trouble with a bright class if they are told that water and mineral matter and carbon dioxid are "digested" in the leaf. And the trouble ought to be heated seven times hot for those who persist in retaining in any form the word "assimilation" in connection with the process of food-manufacture in the green plant. The one defect in what is in other respects an admirable elementary text-book is the retention of that misleading word, even going so far as to call it in one place "assimilation proper," with no apology for it beyond the mere use of quotation marks. Again, if respiration has been correctly defined in zoölogy, it will be easier to draw the distinction between that process and photosynthesis in green plants; and each process can be better understood if the cell is looked upon as the unit of action.

In what way has botany helped the other biological sciences? Certainly, by calling attention to the advantages of a study of the habits of living things and their special adaptations to their natural environment, zoölogy has been made more of an outdoor study than it had been for some time past. This certainly is a

step in the right direction, since it takes the student out into nature's great laboratory, and at the same time teaches him to respect the lower forms of life by showing him that each animal, likewise each plant, has its own life-problems to solve. By studying the animal or plant from the standpoint of its own personal well-being, the student is led to feel a greater respect for their life, and is thus made less selfish in his attitude toward the world in which he lives.

Then, too, the painstaking accuracy of the earlier botanists has not been without its effects upon those working in the other science. The first conception of the cell theory itself came as the result of the study of plant tissues.

We have already pointed out some of the mutual relations between botany and physiology. We may simply add here that we know far more regarding the chemistry of animal digestion as the result of the work of the plant physiologists.

It may be thought that most of the considerations presented are more theoretical than practical, but surely they are not without a practical bearing. In studying the practical benefits to be derived from a combined course in zoölogy, physiology, and botany, we can see that some of them will be direct, others indirect. The direct advantages of the combined course in any one year will depend, naturally, upon the actual order in which the subjects are taken up. If zoölogy precedes physiology, the study of the comparative anatomy and physiology of the lower forms will aid materially when applied to human anatomy and physiology. Thus opportunity will be given for a more careful study of many topics which must otherwise be slighted, for mere lack of time. The way in which botany will be benefited by the previous study of zoölogy and physiology has already been pointed out.

But the advantages of such a combined course are not at all confined to any one year. Such a course cannot be given year after year without exerting a most profound influence upon the teacher. If the three subjects are taught as parts of a larger, broader science, the teacher, at least, will see more and more

clearly the many points of contact between them. And as his own horizon expands, he will impart to his pupils a much broader conception of life in all its varied forms and manifestations; and this is the supreme object which we hold before ourselves in all our educational work.

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